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ABSTRACT

This report describes part of a longer study on sentence comprehension. The long range goal is to identify distinct levels of processing in terms of the types of linguistic and extralinguistic information each level uses. The focus of this part of the study is sentences with filler-gap relations, such as, "This is the girl the teacher wanted to talk to" and "This is the girl the teacher wanted to talk." Forty-eight sentences were constructed modelled on these two examples. The sentences, intermingled with other sentences of varying structures, were presented on a computer-controlled video display to 48 college-student subjects who were instructed to indicate whether or not they thought they understood each sentence, on the basis of an intuitive decision. Another experiment was conducted with sentences in which the verbs prevented possible ambiguity, in order to determine whether or not other information is used in initial comprehension. It was found that readers initially fill a gap in a sentence with the most salient possible filler, and that this strategy is followed even when semantic control information about a verb seems to prohibit it. (AMH)

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COMPREHENDING SENTENCES WITH MULTIPLE FILLER-GAP DEPENDENCIES*

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Theories of sentence comprehension come in two principal varieties. Theories of one variety, which can be termed "interactive", emphasize, in their extreme versions, the grand complexity of sentence comprehension. They view a reader or listener as using a wide variety of types of information in a largely unstructured, unconstrained way. One reason to believe such theories is the fact that people identify words very rapidly when they occur in meaningful sentence contexts.

The other type of theory can be called "autonomous". Such theories attempt to analyze the process of sentence comprehension into simpler component processes. They claim that the possibilities for interaction among these simpler components are severely constrained. In their extreme versions, they claim that the component processes are distinct processing levels, in that they are strictly ordered in terms of when they are initiated, and in that they apply different decision principles to different classes of information. These theories attempt to capture whatever simple order exists in a complex process.

My colleague Lyn Frazier and I are conducting research which we hope will tease apart distinct and separable levels of processing in the course of sentence comprehension. Our goal is to identify distinct levels of processing in terms of the types of linguistics and extralinguistic information each level uses. We have focussed upon a class of sentence constructions that are of special interest in both linguistic and psycholinguistics, sentences with long-distance dependencies between their elements. Our initial focus has been upon sentences with filler-gap relations. Consider sentence 1A, in panel A of the handout. The verb "to talk" in this sentence seems to be missing a subject, and the preposition "to" is missing an object. We refer to the positions of these missing elements as "gaps", following Chomsky's analysis of such sentences. Each gap has a "filler". In the illustration, we have connected each gap to its appropriate filler. Presumably, a person reading or hearing the sentence must do the same.

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The experiment I will report today studied the way in which readers assign fillers to gaps, and attempted to identify both the strategy readers follow in making filler-gap assignments, and the types of information they use in applying the strategy.

We contrasted the comprehension of sentences similar to sentence 1A with comprehension of sentences like 2A. Note that these sentences are identical up to the last word. They are temporarily ambiguous up to this point, and their ambiguity lies in which filler should be assigned to the gap before the verb "to talk". Many people intuitively find Sentence 2A a little harder to understand than Sentence 1A. One purpose of our experiment was to demonstrate that this is in fact the case. Let me describe the experiment, and then go on to interpret this finding, among others.

We constructed 48 sentences modelled on Examples 1A and 2A. Our actual sentences were more complex, and Examples 1B and 2B are actual instances of sentences we used. We wrote several different forms of each sentence, including the forms shown in 1B and 2B. We presented these sentences, intermingled with other sentences of varying structures, on a computer-controlled video display, with the very simple instruction to our 48 college-student subjects that they were to press one button as quickly as possible if they thought they understood the sentence, and another if they found it confusing. We emphasized to our subjects that they should make quick, intuitive decisions. Because of pilot research, we used a mode of presentation in which each word was presented separately, for 350 msec, and instructed our subjects to respond very quickly after the last word of the sentence. We measured the time subjects took to make a response that indicated that they comprehended the sentence, and we measured the probability that they made this response rather than the response indicating that they were confused. Note that, in the critical comparisons, all our sentences ended with the same last few words, so that we cannot attribute any reaction time results we get to differences in word reading time.

On a randomly selected one-third of the trials when subjects indicated that they understood a sentence, we presented a question about the sentence. In the case of interest, we asked of Examples 1B and 2B, "Who would sing those songs?" We recorded and scored the answers.

Our measures of comprehension judgments indicated that sentences like 2 were indeed harder to understand than sentences like 1. As indicated in Panel B, the sentence without a preposition took about 100 msec longer to understand, and subjects reported understanding them 14% less frequently. Interestingly, questions about the two types of sentences were answered with equal accuracy.

We propose the following account of the differences we obtained. A reader, when he or she detects a gap in a sentence, initially chooses a possible filler from earlier in the sentence and assigns it to the gap. The filler chosen is the momentarily most salient one. Generally, this will be the most recent one, "the little child" in Examples 1B and 2B. The reader stays with this single initial assignment until contrary evidence arrives. In Example 1B, which we call a Recent Filler sentence, no contrary evidence arrives. The preposition "for" appears, and, since it is not followed by a noun phrase, it must have a gap after it. The head of the relative clause, "the woman," which must be assigned to some gap as a filler, is assigned to this gap after the preposition. In Example 2B, a Distant Filler sentence, contrary evidence does arrive. The sentence ends without assigning the obligatory filler "the woman" to any gap. Since it must be assigned to some gap, the reader must give up the original assignment of "the little child" to the gap before the verb, and assign "the woman" to this gap. This reanalysis process takes time, and is subject to error, resulting in the comprehension differences we obtained.

We have one piece of evidence that indicates subjects may choose the most salient filler to assign to a gap, not just the most recent. Half of our sentences had a relative pronoun present (parenthesized in Examples 1B and 2B), and half did not. Presence of a relative pronoun may serve to highlight the role of the noun phrase which precedes it - "the woman" in our examples - as the head of the relative clause, and thus make it more salient as a filler. In fact, including a relative pronoun decreased the difficulty of understanding Distant Filler sentences like Example 2B, but not Recent Filler sentences like Sentence 1B. These data can be seen in Panel C. We interpret them as indicating that the relative pronoun makes it more likely that the noun phrase to which it refers will be selected quickly as a filler.

So far, we have identified a strategy of assigning the most salient filler to a gap. Such a strategy, we claim, uses syntactic information, about the grammatical category to which words belong, about the phrase structure rules that apply to them, and, when the argument is worked through in detail, about their subcategorization frames. Is other information, such as semantic or pragmatic information, used in making this initial assignment?

Our experiment contained sentences like Examples 3A and 4A (3B and 4B are actual sentences from the experiment). These are just like our earlier sentences, except that the verb of the relative clause does not permit the possible ambiguity allowed by the earlier ones. The verbs of Examples 3 and 4 are specified for their semantic control information. Verbs like "started" and "decided" require that their own subject be the subject of their complement sentence; verbs like "forced" and "allowed" require that their object be the subject of their complement sentence. We refer to sentences with such verbs as "unambiguous," as contrasted with the temporarily ambiguous sentences of Examples 1 and 2.

If a reader could use the semantic control information present in Sentences 3 and 4 at the same time as the information about grammatical category and phrase structure information, he or she could avoid the mistaken assignment of the most recent filler to the gap in Examples 4A and 4B. Instead, the reader could initially make the correct assignment. In this case, the difficulty we found for Sentence 2B, as compared to Sentence 1B, would disappear in the comparison of Sentences 4B and 3B.

There may, on the other hand, be two or more distinct levels of processing involved in the assignment of fillers to gaps. Our comprehension time measure may tap the products of an early level which uses only syntactic and lexical category information, not semantic control information, to make initial filler-gap assignments. If so, the difference we found between our Recent Filler and Distant Filler sentences would be maintained even in the face of superficially helpful semantic control information. Semantic control information would have no effect at all at the early level of processing, but would be used only at some more advanced level of processing.

In fact, the inferiority of Distant Filler sentences remained when we tested unambiguous sentences. The data from our unambiguous sentences closely mirror the data from our ambiguous sentences. No interaction or main effect involving whether a sentence permitted a temporary ambiguity in filler-gap assignments approached statistical significance. We take this to indicate that semantic control information is not used at the early level of sentence comprehension that our comprehension reaction-time increase taps. This level presumably uses only more purely syntactic information, and operates prior to any level at which semantic control information about a verb can be used.

We do have evidence that semantic control information is used at some later point of processing. One kind of evidence comes from intuitive judgments of sentence comprehension difficulty. Almost all our subjects intuitively judged sentences like 2B to be harder to comprehend than the remaining sentences. Certainly, 4B intuitively seems easier than 2B. We think that these intuitions tap only levels of processing that produce meaningful semantic interpretations of sentences. Unambiguous Distant Filler sentences like 4B seem easy, because the semantic control information blocks the erroneous semantic interpretation that would trigger the intuition of having been misled. Ambiguous Distant Filler sentences, like 2B, are open to such erroneous semantic interpretation, and hence seem confusing. However, our comprehension reaction time measure taps an early, pre-semantic, level of processing at which all Distant Filler sentences share a source of difficulty.

The other type of evidence we have that semantic control information is used at a later point in processing comes from our question answering data. There was no difference in the accuracy with which questions about Recent Filler and Distant Filler sentences were answered. However, semantic control information did have an effect. Subjects answered questions about sentences with unambiguous verbs more accurately than questions about sentences whose verbs permitted a temporary ambiguity, 84% vs. 72%. Semantic control information may be used in assigning meaningful interpretations to sentences after an initial structural analysis is assigned to them. The semantic support a verb with unambiguous semantic control properties gives to a correct structural analysis may make a sentence with an unambiguous verb easier to remember.

Let me sum up. We found that readers initially fill a gap in a sentence with the most salient possible filler. We further found that they follow this strategy even when semantic control information about a verb seems to prohibit

it. We found, however, that semantic control information affected intuitions of sentence difficulty, and the accuracy with which questions about sentences could be answered. We concluded that our sentence comprehension measures tapped an early level of sentence processing which uses syntactic but not semantic control information, while the latter type of information is used later in processing. We intend to continue this research by identifying other levels of processing that occur as distinct, analyzable components of sentence comprehension, and by characterizing each level of processing in terms of the types of linguistic and extra-linguistic information it uses.

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PANEL A: ILLUSTRATIVE SENTENCES

1a. This is the girl$_i$ the teacher$_j$ wanted ____$_j$ to talk to ____$_i$.

2a. This is the girl$_i$ the teacher$_j$ wanted ____$_i$ to talk.

3a. This is the girl$_i$ the teacher$_j$ decided ____$_j$ to talk to ____$_i$.

4a. This is the girl$_i$ the teacher$_j$ allowed ____$_i$ to talk.

PANEL B: EXPERIMENTAL SENTENCES AND DATA

Sentence Type	Example Sentence	Comprehension RT	% comprehension response	% correct question answer
1b. AMBIGUOUS RECENT FILLER	Everyone liked the woman$_i$ (who) the little child$_j$ begged ____$_j$ to sing those stupid French songs for ____$_i$ last Christmas.	1073	77%	72%
2b. AMBIGUOUS DISTANT FILLER	Everyone liked the woman$_j$ (who) the little child$_i$ begged ____$_j$ to sing those stupid French songs last Christmas.	1174	63%	71%
3b. UNAMBIGUOUS RECENT FILLER	Everyone liked the woman$_i$ (who) the little child$_j$ started ____$_j$ to sing those stupid French songs for ____$_i$ last Christmas.	1068	78%	83%
4b. UNAMBIGUOUS DISTANT FILLER	Everyone liked the woman$_j$ (who) the little child$_i$ forced ____$_j$ to sing those stupid French songs last Christmas.	1155	69%	84%

PANEL C: EFFECT OF RELATIVE PRONOUN (Comprehension time, msec)

Type of Sentence	Ambiguous Control Verbs		Unambiguous Control Verbs	
	Relative Pronoun Absent	Relative Pronoun Present	Relative Pronoun Absent	Relative Pronoun Present
Recent Filler (1,3)	1077	1069	1042	1094
Distant Filler (2,4)	1228	1120	1170	1141